Science
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TOXIC

WASTES

A Problem in Search of a Solution

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The guide that accompanies **Toxic Wastes: A Problem in Search of a Solution** of the Science, Technology and Society series was written by Stella Shrum.

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The Science, Technology and Society Series

***STS** is an international science education movement. It represents the first significant change in the science curriculum in 25 years. The STS concept strives to broaden the scope of science education by integrating into science curricula accurate presentations of the nature of science, the nature of technology and the interactions of science and technology with each other and society. This video series provides illustrative examples of the relationships between science, technology and society.*

The STS connections describe products and processes; environmental and ethical issues relating to the interrelationships among science, technology and society; how scientific knowledge develops and the influence of society on scientific and technological research; and science and technology related careers. The contexts are meant to be relevant to students' lives and also prepare students for life in a rapidly changing society in which science and technology play an important role.

To the Teacher

This video program and guide are meant for use with students, to bring the topical issue of toxic waste into the classroom in a balanced way. One of the most important tasks of science teachers is to help students understand the science behind controversial issues in order to promote the idea that, as citizens, we all have a role to play in solving environmental problems—but first we must understand them.

The video provides an opportunity for discussion of the advantages and disadvantages to society of continuing to use and produce substances that can potentially cause harm. The information in this video should help students to understand the problem, while providing hope for a solution. It should help students make choices that will have a positive influence on the environment.

The program is suitable for use as an introduction to a unit in chemistry or as the culminating activity in a unit of integrated science, and has curricular fit with the STS connections in several of the Alberta Senior High Science programs of study.

After viewing this video, students should be able to:

- explain what toxic wastes are
- categorize toxins according to the damage they cause
- describe some of the effects caused by toxic wastes
- name some significant common toxic wastes and describe their sources
- describe some ways in which industry is minimizing the release of toxic wastes
- briefly explain the process by which wastewater is treated in a large city

- describe some ways in which individuals, in their everyday activities, may contribute to solving the toxic waste problem.

Overview

Could toxic wastes eventually destroy our planet? In a light-hearted introduction to a serious topic, the monster "Toxilla" directs viewers' attention to the subject of toxic wastes. Alarm and panic are common responses to this potential threat to our environment; however, once we understand the problem and discover the ways it is being addressed, particularly how individuals can be part of the solution, toxic wastes are not so formidable.

Understanding the Problem

We sometimes refer to our planet as fragile when in reality it is practically indestructible, having withstood ice ages, bombardments of cosmic radiation, and collisions with comets and meteoroids. However, one aspect of the planet may well be too delicate to withstand toxic wastes—the ecosystem that sustains human life.

In the last 100 million years, numerous species have come and gone and the physical features of Earth have changed dramatically. Should we destroy the ecosystem that sustains us, the planet will survive and other creatures who thrive under the new set of conditions will rise up in our stead. It is the set of conditions favourable to human life that is most at risk of being altered by toxic wastes and other environmental hazards. Largely through scientific research, we are coming to understand threats to the environment and developing the knowledge and technologies to alleviate them. "Toxilla" cannot destroy us as long as we have the will to use our powers of learning and reasoning to find ways to reduce the threat of toxic wastes.

Understanding what makes a substance toxic can help lessen unreasonable fears of chemicals, preventing us from making hasty decisions. **Toxic substances react with the chemistry of a living organism in such a way as to impair or threaten life.** One way of categorizing toxins is according to the damage they cause.

Corrosive substances destroy living tissue by reacting with it. These include strong acids, bases and oxidizing agents; *e.g., sulphuric acid and ammonia (both used in fertilizer production), sodium hydroxide (in drain cleaner), chlorine gas (pulp bleaching agent), hydrogen peroxide (disinfectant), sodium hypochlorite (in household bleach).*

Metabolic toxins interfere with biochemical processes such as cellular respiration; *e.g., carbon monoxide (produced from the incomplete combustion of fuels, also present in cigarette smoke), hydrogen sulphide (naturally occurring in sour gas), cyanide (rodenticide), formaldehyde (tissue preservative), aniline (textile dye), sodium nitrate (meat preservative), ozone (in photochemical smog).*

Neurotoxins interfere with the functioning of the nervous system; *e.g., nicotine (in tobacco products), lead compounds (a byproduct of combustion), methyl mercury (present in waters near the effluent discharge from manufacturers of electrical*

equipment), organophosphates, carbamates and organochlorinates (all present in pesticides), methanol (a solvent in antifreeze, paint, ink).

Mutagens are capable of affecting genes and chromosomes by altering the structure of the DNA and RNA, thereby inducing mutations in the genetic code. This results in changes to the genetic structure in future generations. *Examples of mutagens include radiation (from X-rays) and benzopyrene (in coal tar, cigarette smoke and charbroiled meat).*

Note: *Even though it is described as such in the video, sodium nitrate is not considered a mutagen in humans, but rather a metabolic poison. Sodium nitrate is added to cured meats for protection against botulism. Nitrate compounds are part of nature's cycle of decomposition of organic matter and are naturally present in many food crops and water sources. They are only a danger if ingested in relatively large amounts.*

Teratogens act on the human embryo when it is in the uterus causing developmental abnormalities. The factor usually has to be present during the first three months of gestation when cell differentiation is most rapid. *Examples of teratogens include radiation (X-rays), ethanol (in alcoholic beverages), viruses (such as rubella).*

Carcinogens are substances that cause cancer, or uncontrolled cell division. *Suspected carcinogens include benzopyrene, benzene (a gasoline additive), certain dioxins (in chlorine bleached pulp), carbon tetrachloride (a solvent), formaldehyde (in pressed wood products), heavy metals such as beryllium, and cadmium, nitrosamines (may form in the gut when meat containing nitrates and nitrites are eaten), vinyl chloride (used to make PVC plastics).*

A toxic substance becomes hazardous when it is placed in the environment where it can come into contact with living things and potentially cause harm. The Workplace Hazardous Materials Information System (WHMIS) describes another way of categorising substances that could become toxic wastes:

- **Corrosive substances** eat and wear away at materials; e.g., *battery acid, drain cleaner.*
- **Toxic substances** are poisonous or lethal in small quantities. Some of these materials cause immediate and serious toxic effects; e.g., *rat poison, antifreeze, insecticide,* while others are slower-acting and cause other toxic effects; e.g., *mercury, lead, cadmium.*
- **Flammable and combustible materials** can ignite when in contact with a spark or flame; e.g., *lighter fluid, gasoline.*
- **Biohazardous materials** contain infectious pathogens; e.g., *viruses and bacteria.*
- **Dangerously reactive materials** can explode or produce deadly vapours; e.g., *aerosol cans containing paints or solvents.*
- **Oxidizing materials** are unstable chemicals that undergo reactions very easily, possibly releasing toxic gases, or they support combustion by providing a source of oxygen; e.g., *bleaching agents such as chlorine or hydrogen peroxide and potassium permanganate, which may be used as a water disinfectant in rural areas.*

WHMIS symbols

CLASS A		**Compressed Gas**
CLASS B		**Flammable and combustible material**
CLASS C		**Oxidizing material**
CLASS D		**Poisonous and infectious material** 1. Materials causing immediate and serious toxic effect
		2. Materials causing other toxic effects
		3. Biohazardous infectious material
CLASS E		**Corrosive material**
CLASS F		**Dangerously reactive material**

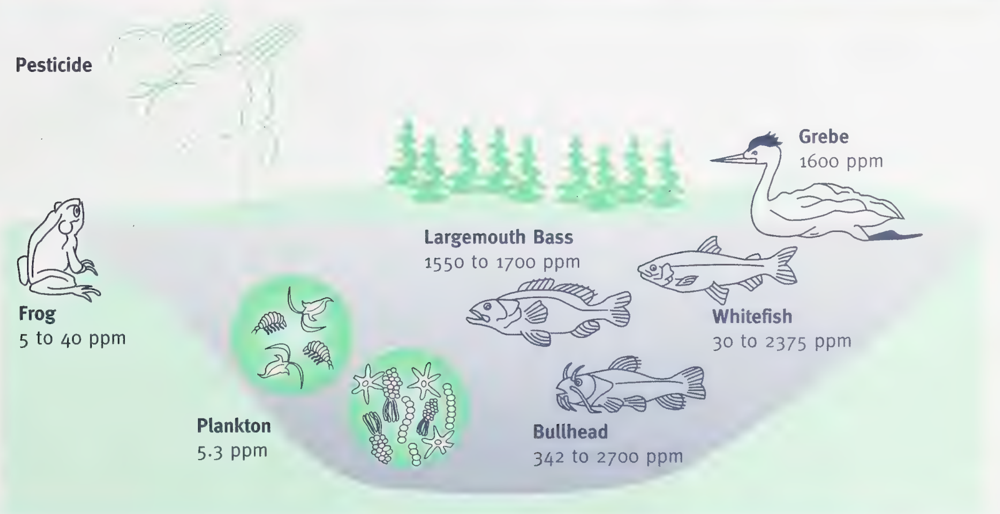
Wastes are substances for which we have no further use. **Toxic wastes**, therefore, are hazardous substances we wish to discard. Worldwide, humans now generate more than 6 billion tonnes of hazardous wastes and wastewater, in Canada almost 6 million tonnes.

Hazardous wastes are produced by a variety of human activities such as mining, smelting, oil production, refining and distribution, agriculture and energy production, and the manufacture and use of products including pesticides and herbicides, chemical preservatives and solvents, paints, dyes, explosives, rubber and plastic, batteries, pulp and paper, pharmaceuticals, fabric and leather. When we bring these products into our homes, then use or discard them, we add to the toxic waste problem.

Accidental spills of hazardous substances can occur at manufacturing sites, during their transport to another site, or as they are being used at home or on the farm. Toxic wastes may be in the form of solids, liquids or gases and may enter the air, water or soil, with air emissions, discharge effluents or discarded solids (solid waste).

As toxic substances move in the environment they create risks for humans and other species, either by the immediate effects of exposure or by gradual accumulation of smaller amounts. Toxic substances can also become bioconcentrated in the food chain, accumulating to the point of toxicity in third-order consumers, including humans.

The Concentration of a Pesticide in a Food Chain



LD 50, the dose that is lethal for 50% of a specified population, is often used to describe the toxicity of a chemical. It can vary immensely from species to species and also with age of the individuals; for example, older people and children may be more susceptible than others. Most LD 50 values are determined with experimental animals and extrapolated to humans. Therefore, the careful reasoning and judgment of expert scientists must translate the values into human terms.

Every chemical has some set of exposure conditions under which it is toxic and a set under which it is not toxic. Even table salt is toxic to humans if enough is ingested. We must be concerned not only with what a toxic waste does, but also in what concentrations it is harmful.

In the past the planet was believed to be large enough to dilute and render harmless whatever we put into it. Then it was believed that we had fouled the planet with toxic wastes almost to the point of destroying it. We now know that certain hazardous substances can be tolerated in relatively large amounts, but for others even the smallest amount has potential harmful effects. Many chemicals can be toxic under some set of conditions; however, we usually apply the word toxin or poison to a relatively small number of substances that cause harm or are lethal in very small quantities. Even in a diluted form, these should not be released into the environment.

Solutions to the Problem

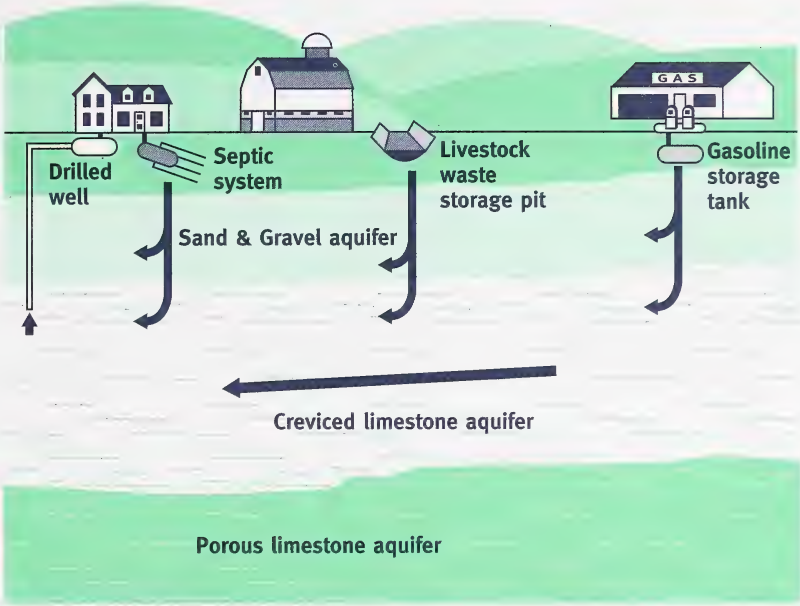
Paranoia about toxic waste can prevent us from thinking rationally about the problem, while clear-minded reasoning, with the help of scientific facts, can show us possible pathways out of the toxic waste dilemma. The first steps are to define the problem we are dealing with, then gather relevant information (this is where the scientists are heavily involved) about the problem and then develop solutions. Often technologists are involved in the solutions, but we all have a role.

Toxic substances that enter the air can affect the most living things because they can be widely distributed in a very short time, and recapturing them is nearly impossible. Humans, for example, inhale large volumes of air, about 20,000 litres per day, and with each breath we take in any toxins that may have contaminated the air.

Discharge liquids, even when contained in settling ponds or containers, often eventually make their way into waterways and contaminate nearby aquatic ecosystems and underground groundwater. It is very difficult to remove toxins from water systems, particularly from groundwater.

Solid wastes are probably easiest to contain, but storing them for long periods of time in containers or incinerating them may be a financial burden for society. Not too many years ago most toxic wastes were disposed of with other wastes in landfills or waterways—no special treatment was given them. Now we have in place strict regulations against dumping hazardous wastes and have developed elaborate methods to deal with them. Following are various ways society is addressing the toxic waste issue.

Agricultural Runoff Wastes



Minimization

The best solution is not to produce the toxins in the first place, but it seems to be difficult for society to give up the products that require toxins in their production or the technologies that produce toxic substances. The next best control of toxic wastes is to produce as little as possible of the offending substance and not to release any into the environment.

In the petroleum industry the emission of volatile hydrocarbons has been reduced by covering tanks, maintaining storage tanks at low temperatures and using 'closed in' connectors. The system used by the Dow Chemical Company to contain methanol as it is being transferred between containers is described in the video. Specialized scrubbers are in place at many industrial sites to remove toxins from smoke-stack emissions, and other industries have settling ponds to collect hazardous substances and treat them before releasing waste waters.

Alternatives

Products can be reformulated to require less or no toxic substances. Current examples include the phasing out of solvent-based paints and inks and using less-toxic substitutes in wood preservatives; as well, lead compounds are no longer added to gasoline. There are many toxic household substances for which substitutes can be used.

Instead of:	Use:
bleach	hydrogen peroxide, vinegar and borax
drain cleaner	a plunger, baking soda and vinegar
moth repellent	cedar chips, dried lavender petals
portable batteries	rechargeable or solar batteries
carpet cleaner	club soda, salt, cornstarch
ant killer	borax, diatomaceous earth
slug killer	stale beer set out in containers
aphid spray	soap solution, blended garlic and onion tops
oil-base paint	water based paints made with natural ingredients, whitewash made with limestone

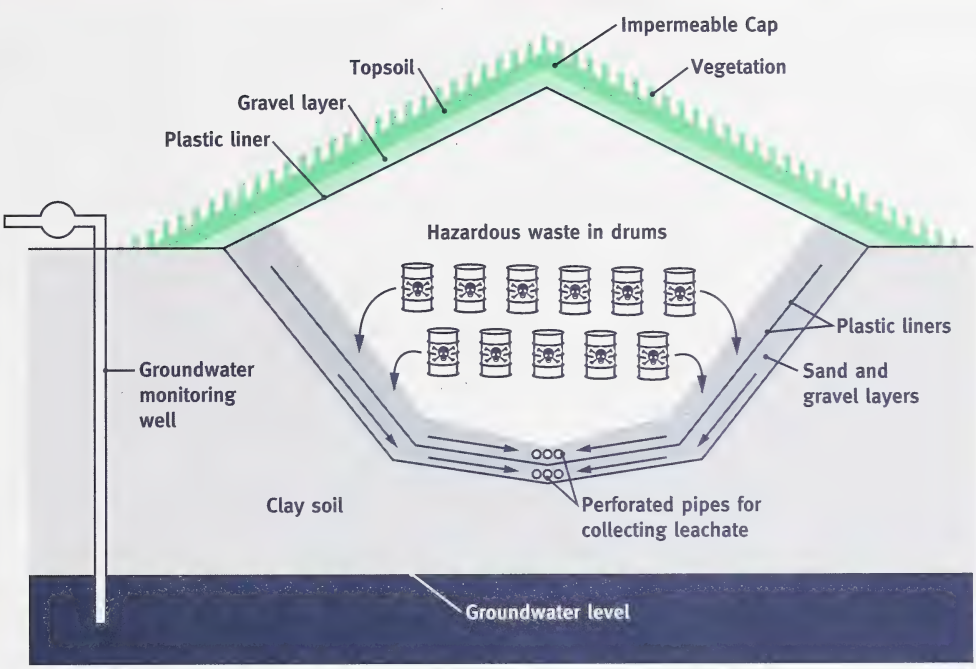
Every time a person lights up a cigarette they are adding toxic carbon monoxide, benzopyrenes and a host of other harmful substances to the nearby environment. The alternative is to give up smoking.

Containment

Permanent storage in secure sites may be the only way to contain certain toxic compounds. In deep well disposal, liquid effluents are pumped into deep underground caverns within impermeable rock formations.

Secure landfill sites, such as is shown on page 9, consist of plastic-lined excavations in clay soil with sand and gravel on the bottom to collect leachate if it should escape from the hazardous waste contained in drums. The site must not reach the level of the groundwater and the groundwater must be monitored for possible contamination. There must also be an impermeable cap on the site to prevent natural precipitation and runoff from entering it.

Industrial Waste Disposal – Containment



Treatment

Sometimes it is permissible to release a substance if it is sufficiently diluted, but the better route is always to detoxify it. Chemical treatments involve precipitation of dissolved toxic substances from the effluent and removal as a solid. Since some solids thus formed are soluble in acidic solutions a further step may be taken in which the substance is fixed in a material such as portland cement to prevent any leaching into the environment.

Breaking down substances into their harmless components is a method that can be used only with a small proportion of toxic wastes. When natural or genetically altered microbes are used to break down specific toxins, the process is called bioremediation. One method involves separating out natural bacteria that feed on a particular toxin in a polluted environment and reproducing them under ideal conditions until a sufficient number are present to detoxify a site. A bioreactor is illustrated on page 11.

In incineration, the offending substance is burned at a sufficiently high temperature to break it down to simple compounds such as carbon dioxide and water or the component elements. This is the final step used at the Swan Hills Waste Treatment Plant, when no other method will detoxify a compound.

On the following page, the steps by which special waste is transported to and processed by the Swan Hills Waste Treatment Plant are outlined.

Swan Hills Waste Treatment Plant Process

START

1 **Waste Enters the System** Many businesses and households generate small amounts of special waste. Households can dispose of waste during a community toxic roundup, while businesses dispose of small quantities of waste at Transfer Stations. Businesses that consistently generate waste must identify the chemical and physical properties.

2 **Waste Collection** Transfer Stations are located across Alberta. Waste generators transport their special waste to these stations, although larger quantities are transported by the system directly to the Treatment Centre.

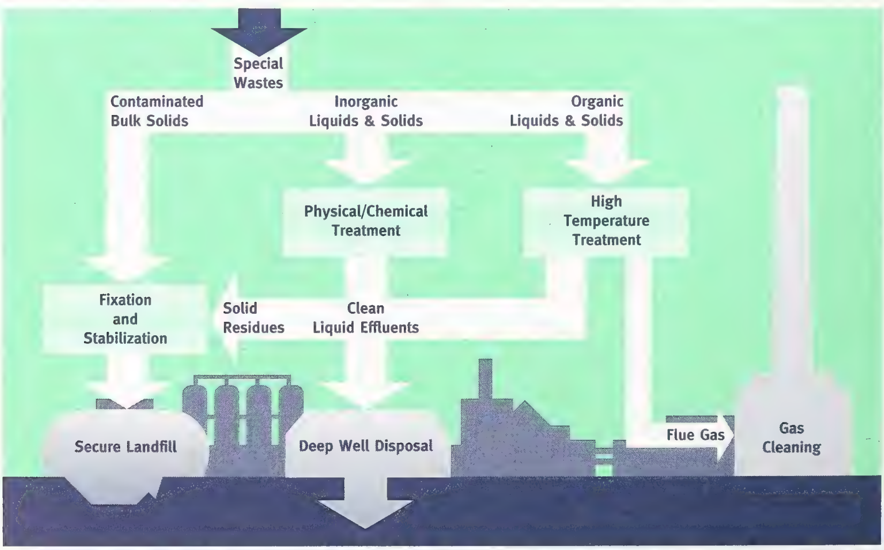
3 **Waste Documentation** A waste manifest accompanies each shipment from the point of generation through disposal. The multi-part form describes the generator, carrier, receiver, waste type, form, volume and shipping information. Government agencies receive copies to track shipments to ensure safe transport.

4 **Transportation Network** Chem-Security (Alberta) Ltd. manages the transportation system and collects waste from Transfer Stations or a generator's site. Two large steel containers are located on the trailer of each truck, and drums of waste are lifted into these safety containers for transport. Specially designed vehicles haul bulk liquids and solids.

5 **Road Safety** Trucks hauling special waste have placards that identify the type of waste being hauled. All trucks are checked thoroughly before departure and are inspected en route.

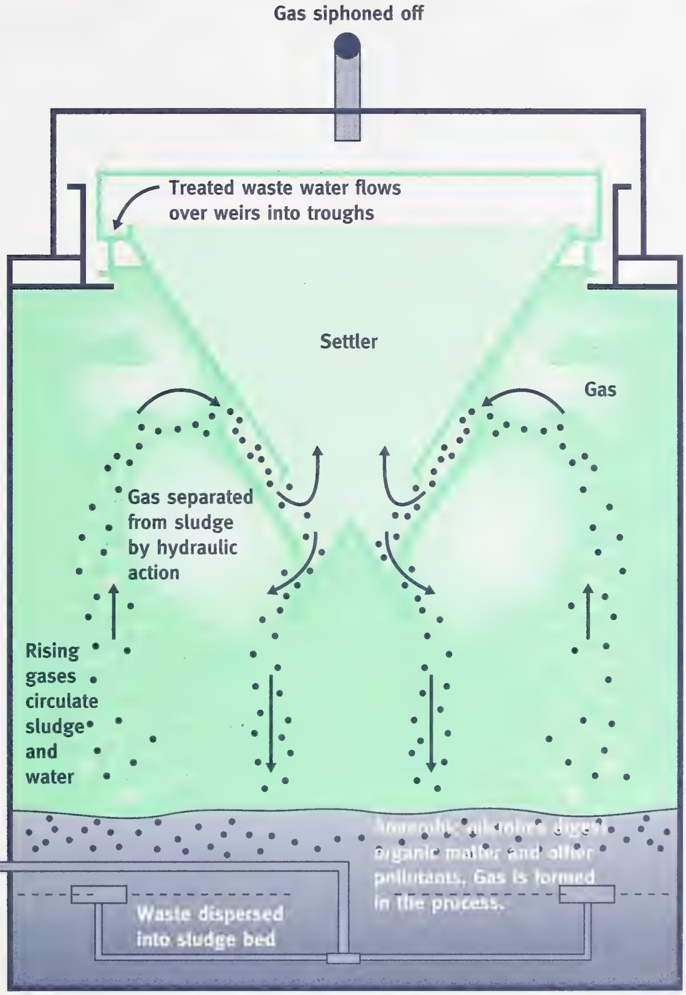
6 **Verification and Analysis** All wastes received at the Treatment Centre are assigned an identification number as a record of treatment and disposal. The Centre's laboratory confirms that the waste matches the description on the generator's waste profile sheet, and waste previously approved for treatment and disposal undergoes a 'fingerprinting' procedure. The lab then verifies that treatment and destruction processes are appropriate and sufficient.

7 **Treatment Processes**



Inside a Bioreactor

In the oxygen-free environment of a bioreactor, anaerobic bacteria can efficiently break down toxins in pulp mill effluent. The waste water is pumped into a bed of microbes which digest the pollutants. Gases formed in the process circulate cleaner water to the top of the tank where it is drawn off.



Clean-up of spills and contaminated sites

Clean-up of contaminated sites can involve hauling away soil and incinerating it or treating water to remove the toxin. Contaminated soil usually has to be removed from a site and stored in impermeable containers or incinerated. Firefighters and other specially trained individuals are called to spill sites and have the equipment and chemicals to mop up the residues. For example, an acid spill will usually be neutralized with an appropriate base before it is diluted with a large amount of water. Then it can usually be safely flushed into a drain.

A mercury spill at a school site would be treated differently. Because of the toxicity of mercury vapour, every last trace must be removed with a vacuum device or by treatment with isopropanol and sulphur to convert the mercury to mercury (II) sulfite. A spill of ammonium nitrate fertilizer would be treated with sodium hydrogen sulfite to reduce the potential of explosion.

Activities for Students

1. Use a reference source such as a dictionary of chemicals or a medical book to find the sources and toxic effects of each of the following substances:

   dioxin, methanol, formaldehyde, arsenic, dieldrin, chromium, lead, pentachlorophenol (wood preservative), benzene, selenium, cadmium, xylene, toluene, acetone, chloroform.

2. Complete this chart by placing examples of the toxic wastes produced in each block; then review your chart to suggest ways of reducing the release of each toxic waste.

Category of Emission

Source	air emissions	liquid effluents	solid wastes
industrial			
commercial			
agricultural			
domestic			

3. Prepare an inventory of the substances in your home and school that could potentially become toxic wastes. How are they labelled? How are they handled? What plan is in place to dispose of them when they are no longer needed? List some alternatives that might be used instead of these particular substances.

4. Look in a book on human biology to find out how carbon monoxide acts as a metabolic poison and how organophosphate insecticides act as neurotoxins.

5. Use a reference source to find the relationship between chelation therapy and heavy metal poisoning.

6. Take a visitors tour of the Swan Hills Waste Treatment Plant. Go prepared with some questions to ask the tour guide.

7. You heard in the video how a chemical company 'recaptures' methanol vapour that escapes from containers when it is being transferred. Residual vapour is then scrubbed with water.

   a. Explain, on the basis of hydrogen bonding, how water can be used to 'scrub' methanol out of air. Describe an analogous situation where methanol is used to remove water from a fuel.

   b. The video states that a similar problem exists at service stations—when gasoline is being pumped into cars, some of it vaporises and escapes into the air. Suggest a design for a technological solution for this problem at gas stations. Draw a sketch of your design.

8. Copper ions are acceptable in water effluent at a concentration of 5.0 ppm. A technician tests for copper ions in a water sample and finds the concentration to be 0.0012 mol/L. Perform the calculations to determine if this is within acceptable limits.

9. Copper in its ionic form is considered to be a toxic substance in concentrations above 5.0 ppm. There are various ways of removing copper

ions from water. One is to use another metal to displace it from solution.

a. Refer to an activity series to find a possible metal that could be used to displace copper from solution and design a procedure for testing it. Another method involves precipitating the copper ions in an insoluble compound.

b. Use a table of solubility to find an appropriate compound for precipitating copper ions from aqueous solution. Design and test a procedure using this principle. **Note:** *Check with your teacher before proceeding and don't discharge any solutions containing copper ions into the environment.*

10. Imagine you are a safety officer and that a hazardous substance such as mercury has spilled in the lab. Do some research to find out the procedures you would follow to clean it up and keep those nearby safe from harm.

11. In various parts of the world environmental accidents have occurred in which toxic substances have been released with disastrous results. Do some research into the following case studies, explaining the causes of the release, the toxin involved and what it was being used for, the health effects on nearby residents, and how such an incident might have been prevented.

    a. Love Canal near Niagara Falls, N.Y.

    b. Minimata, Japan

    c. Bhopal, India

    d. Chernobyl, Ukraine

12. Alberta recently passed a law requiring owners of contaminated land to clean up the mess before the land can be sold. A man in Ryley, Alberta, is contesting the law because he says the previous owners contaminated it without his knowledge. Who do you think should be responsible for cleaning up contaminated sites?

13. The Swan Hills Waste Treatment Plant is the only toxic waste centre in Western Canada and the only one in Canada able to destroy PCBs, the suspected toxic/carcinogenic waste from electrical transformers. There is concern, however, that transporting toxic wastes over great distances to Swan Hills is a danger to communities along the route, because of accidents. On the other hand, accidents, fires or vandalism can cause release at storage sites. Discuss this issue, outlining the advantages and disadvantages of each alternative.

14. We continue to use many toxic substances because we perceive them as providing some benefit to us. Prepare a chart outlining the risks and benefits of a particular toxic substance that is used frequently. Some examples you might consider are X-rays, lead-acid car batteries, pressed wood products, insecticides and herbicides.

References

Armour, Margaret-Ann, et al. *Hazardous Chemicals Information and Disposal Guide*. Edmonton: University of Alberta, 1987.

Braaten, A., et al. *Visions 1*. Toronto: Gage Educational Publishing Company, 1992.

Edwards, L., et al. *Visions 2*. Toronto: Gage Educational Publishing Company, 1992.

Envirodial. Alberta Special Waste Management Corporation. (*In Edmonton call 422-5029; outside of Edmonton call 1-800-272-8873*)

Harte, John, et al. *Toxics A to Z: A Guide to Everyday Pollution Hazards*. Berkeley, CA: University of California Press, 1991.

Joesten, Melvin D., et al. *Chemistry: Impact on Society*. New York: Saunders College Publishing, 1988.

Ottoboni, M. Alice. *The Dose Makes the Poison*. New York: Van Nostrand, 1991.

Winter, Ruth. *A Consumer's Dictionary of Household, Yard and Office Chemicals*. New York: Crown Publishers Inc., 1992.

Notes

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